Fusor

An Easy to Construct, Fusion Reactor
Based on Inertial Electrostatic Confinement

Background

- Why do I choose to fuse?

- I am an Amateur Scientist!
- The “Hands-on Imperative”

Amateur Scientist?

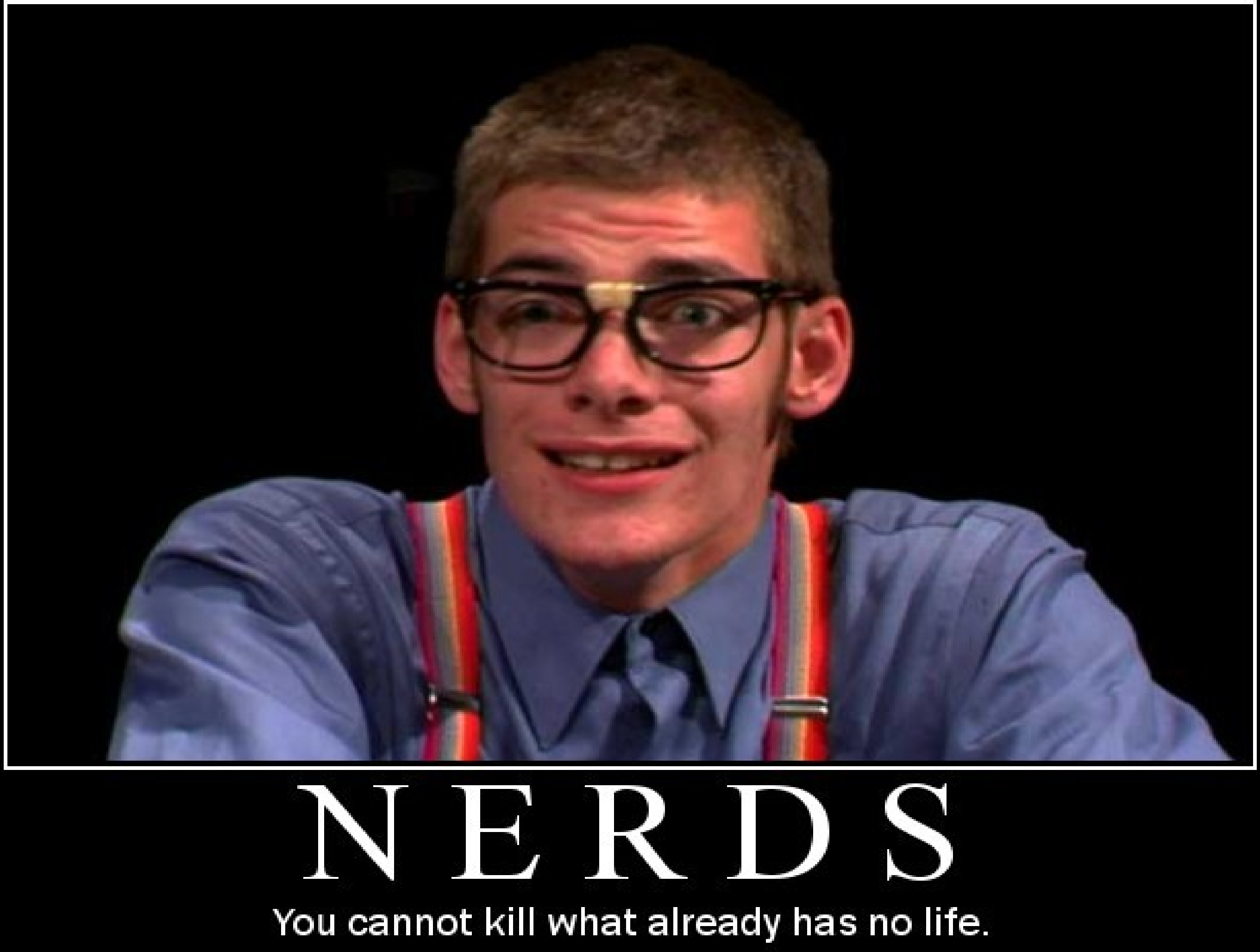
- Where did this originate?

  Cold War – Need for scientists

  Government and Educational support for young people to enter the world of science and engineering.

  Availability of materials at reasonable prices.

I was this guy

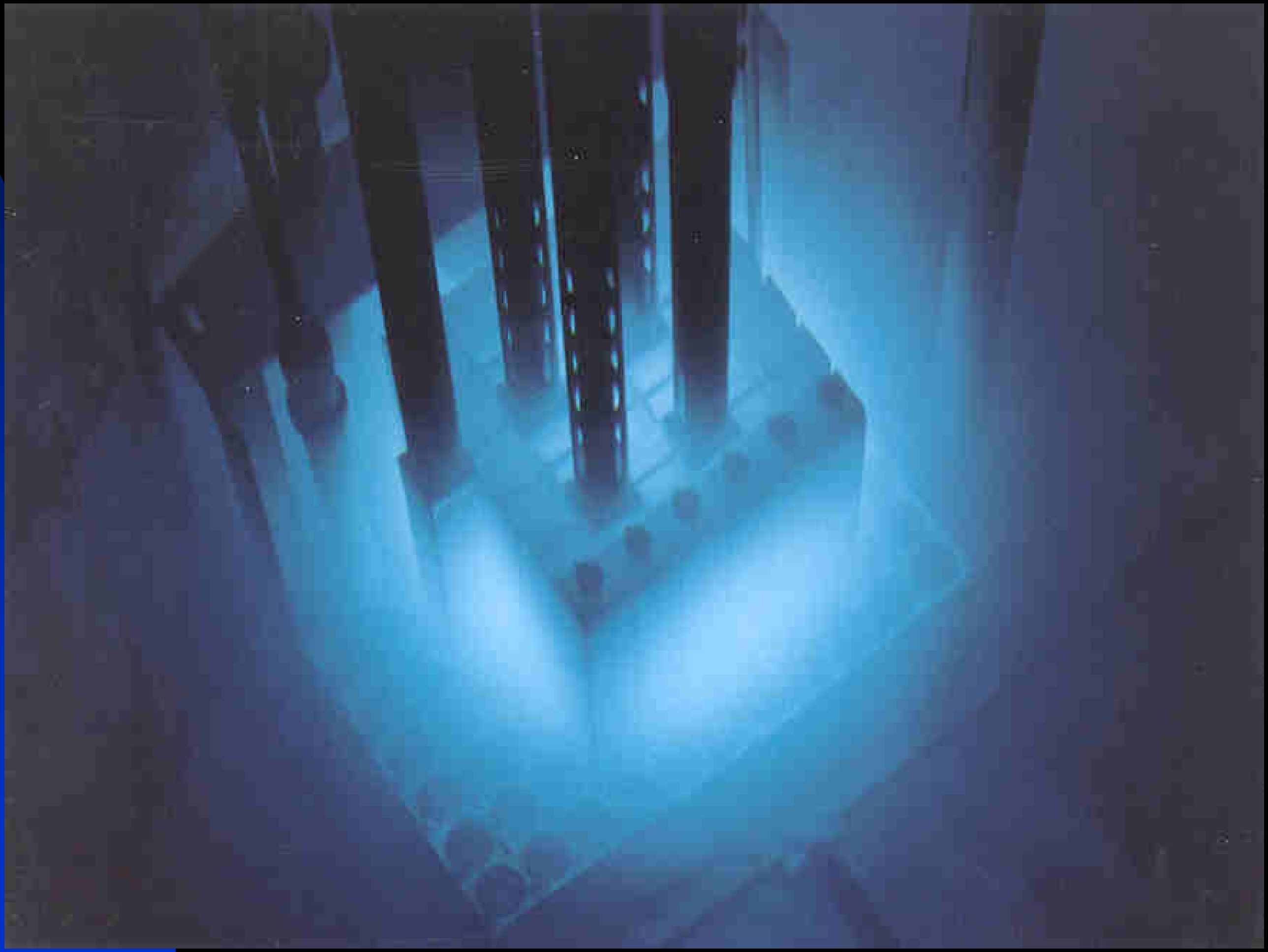


My first Chemistry Set

Eisenhower’s 1953 UN Speech
National Nuclear Effort

This program supplied schools, research institutions, hospitals and businesses with information, equipment and isotopes

A Trip to UVA’s Reactor



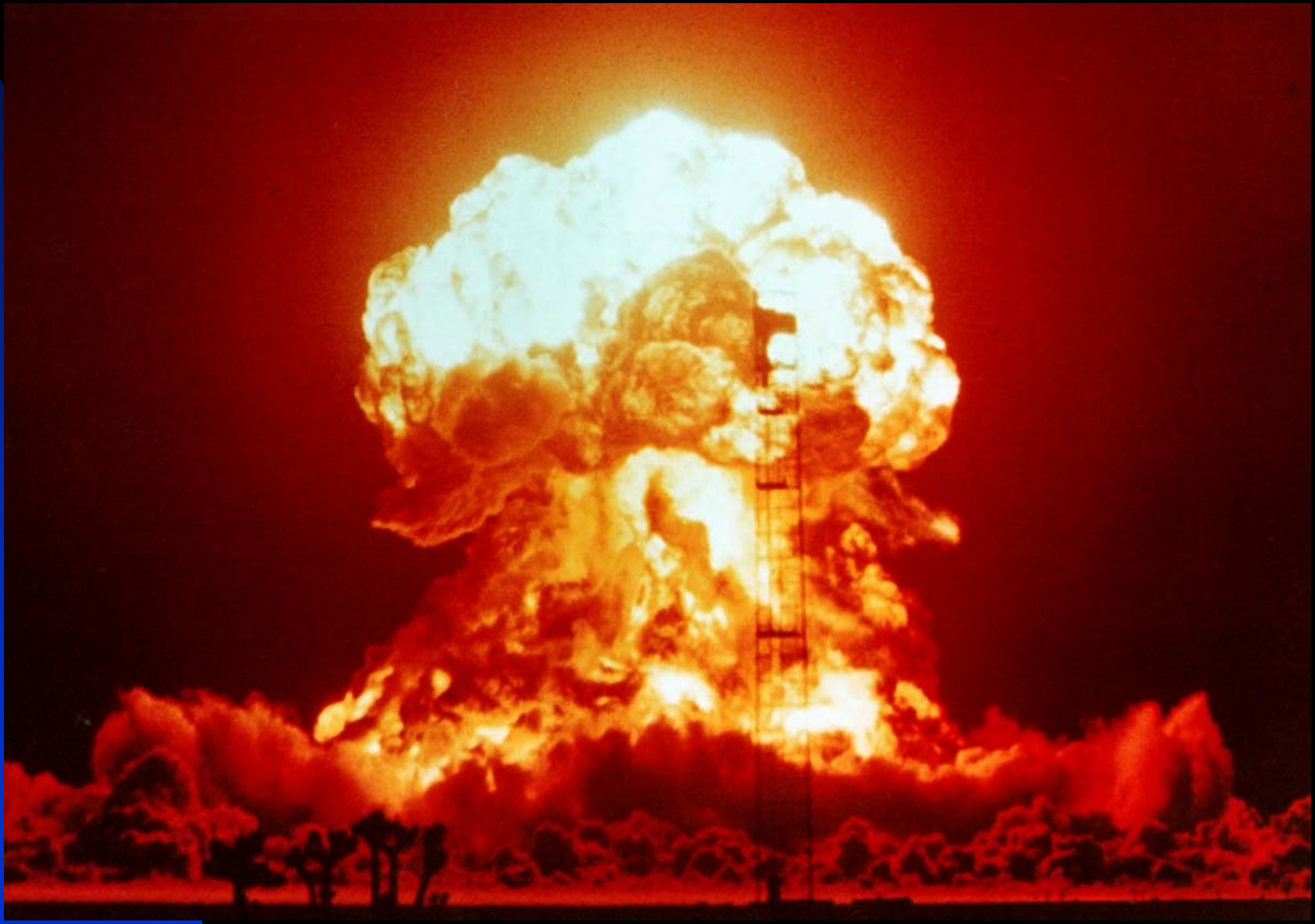
My First Geiger Counter - 1956 AN-PDR27

Radium Dials

Uranium Ore

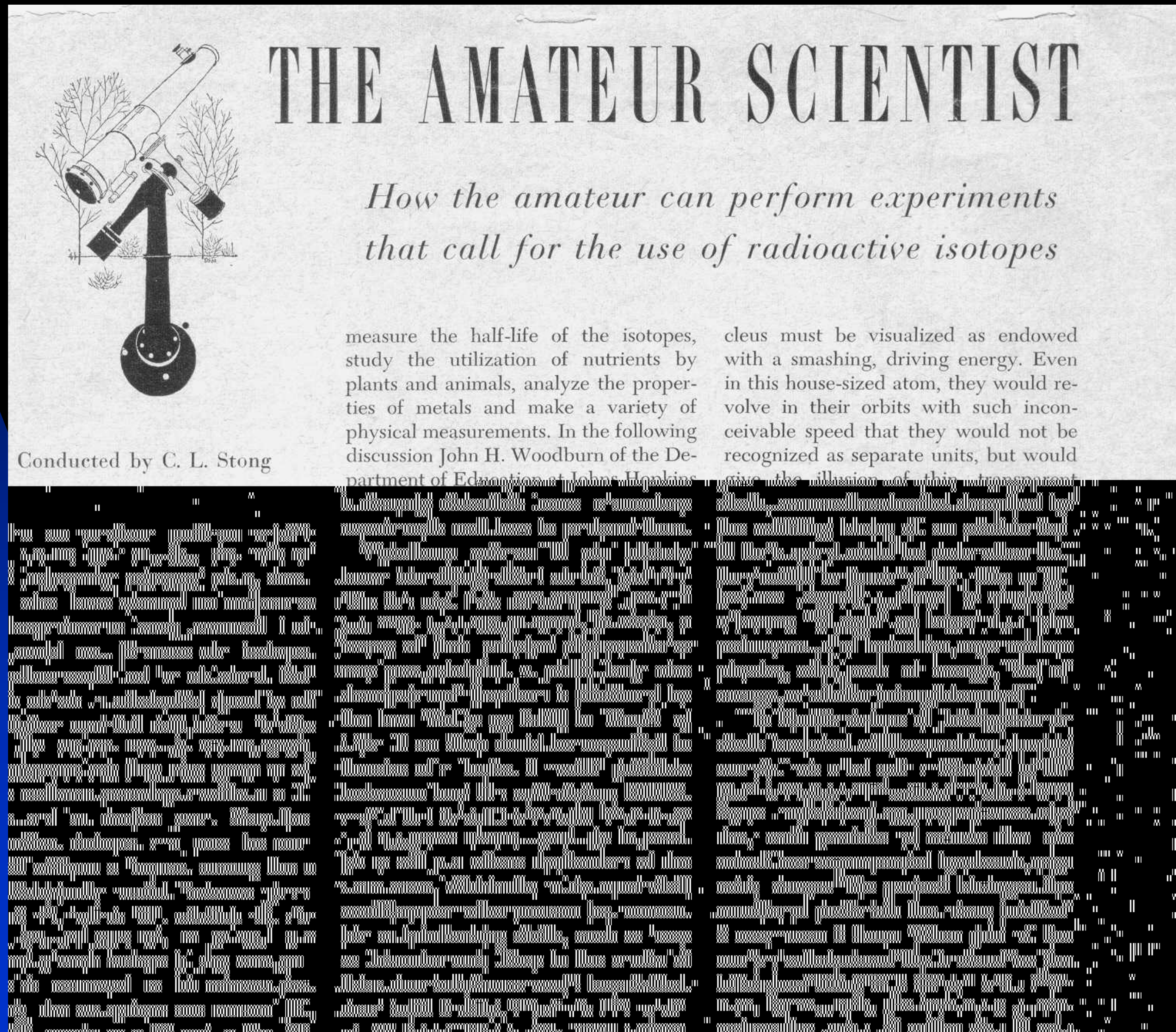
Teapot Series – MET shot – Fallout on Richmond

Evaporated Bird Bath Residues



The Hook

1960



THE AMATEUR SCIENTIST

How the amateur can perform experiments that call for the use of radioactive isotopes

Conducted by C. L. Stong

measure the half-life of the isotopes, study the utilization of nutrients by plants and animals, analyze the properties of metals and make a variety of physical measurements. In the following discussion John H. Woodburn of the Department of Education at Johns Hopkins

cleus must be visualized as endowed with a smashing, driving energy. Even in this house-sized atom, they would revolve in their orbits with such inconceivable speed that they would not be recognized as separate units, but would

Many companies sought to sell radio-nuclides to the amateur and educational market at impulse buy prices.

I bought several of the Abbott Labs super 9 packs

ABBOTT LABORATORIES

RADIO-PHARMACEUTICALS, P. O. Drawer R, OAK RIDGE, TENNESSEE

RADIOISOTOPES FOR LABORATORY EXPERIMENTATION

The listing below supplies some of the more useful isotopes in amounts suited for laboratory experimentation. The quantities are generally licensed by the Atomic Energy Commission and no by-product license is required.

2-Pack List 7712

10 μc	P-32	NaH_2PO_4
10 μc	I-131	NaI

The I-131 may be substituted by any item listed in the 9-Pack

$7.50 Air Mail Prepaid

9-Pack List 7711

10 μc	P-32	NaH_2PO_4
10 μc	I-131	NaI
50 μc	Cr-51	Na_2CrO_4
50 μc	S-35	Na_2SO_4
10 μc	Zn-65	$ZnCl_2$
10 μc	Ca-45	$CaCl_2$
1 μc	As-74	Na_3AsO_4
1 μc	Hg-203	$Hg(NO_3)_2$
1 μc	Co-60	$Co(NO_3)_2$

$18.00 Air Express Prepaid

IMPORTANT

The isotopes listed above are supplied in 5 ml H_2O contained in 10 ml capacity screw cap vial.

In some cases, no radiation can be detected through the glass vial.

Instructions for placing orders:

SHIPPED FRIDAY ONLY.

1. Specify package, 2-Pack or 9-Pack.
2. Specify shipping date, giving at least one week's notice.
3. Orders received from persons under 21 years of age must be countersigned by parent or school faculty member.
4. ITEMS MAY NOT BE RETURNED FOR CREDIT.
5. PAYMENT TO ACCOMPANY ORDER.

Effective May 1963

Atomic Corporation of America

Another of the suppliers I used

ISOTOPICS

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14725 ARMINTA STREET PANORAMA CITY, CALIFORNIA (91402)

VOL. I SEPTEMBER 1963 No. 1

UPDATE YOUR SCIENCE COURSES WITHOUT CHANGING CURRICULUM

Have you felt recently that your teaching efforts have come to naught? Do you feel that you have worked yourself into a pedagogic cul-de-sac? Is science progressing while your class material is in the same condition as it was when you first got that wide-eyed idea to elevate humanity by teaching it where to find its boot-straps?

Don't weaken now, all is not lost. You may still save humanity along with your sanity. Science has marched on and following along in its wake is not nearly as difficult as you had imagined.

The most powerful tool for scientific instruction yet devised is easily available to you and at a price which any school can afford. THE RADIOACTIVE ISOTOPE. The entire field of radioactive tracers is open to you and your classes and you don't have to be a nuclear scientist to use it.

An ordinary purchase order can bring you this material in license-exempt quantities for immediate use as a classroom demonstration or for student use where they are asked to perform experiments in biology, zoology, chemistry or physics. Isotopes are sent through the mails and will reach you anywhere in the United States or possessions within two or three days.

RADIOACTIVE ISOTOPES

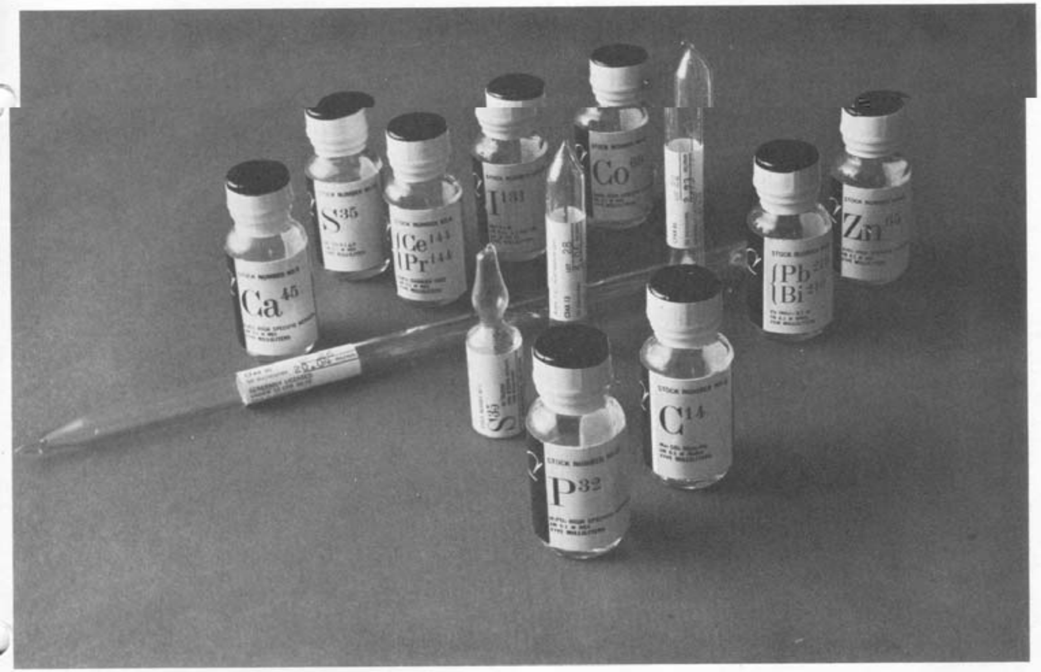
	PROPERTIES					PRICES			
ISOTOPE	CHEMICAL FORM	HALF LIFE	BETA ENERGY in MEV	GAMMA ENERGY in MEV	LIST #	QUANTITY A 0.1uc	B 1uc	C 10uc	D 50uc
IODINE — 131	NaI	8.08 Days	0.608 et al	0.364 et al	110	$	$	$ 4.00	*
PHOSPHORUS — 32	NaH_2PO_4	14.3 Days	1.701	None	205			4.00	*
CALCIUM — 45	$CaCl_2$	163 Days	0.254	None	310		4.00	10.00	*
CARBON — 14	Na_2CO_3	5568 Yrs.	0.155	None	330		4.00	8.00	15.00
CESIUM — 137	CsCl	30 Yrs.	0.51 et al	None	350		4.00	*	*
BARIUM — 137m	$BaCl_2$	2.6 Min.	None	0.662					
CHLORINE — 36	HCl	308,000 Yrs.	0.714	None	370	4.00	8.00	*	*
CHROMIUM — 51	$CrCl_3$	27.8 Days	None	0.32, EC	390		4.00	6.00	12.00
COBALT — 60	$CoCl_2$	5.27 Yrs.	0.306	1.17, 1.33	400		4.00	*	*
IRON — 59	$FeCl_3$	45.1 Days	0.462 et al	0.191, 1.098, 1.289	430		4.00	*	*
NICKEL — 63	$NiCl_2$	85 Yrs.	0.067	None	450		4.00	*	*
SODIUM — 22	NaCl	2.6 Yrs.	0.58 B+	0.511, 1.28	510	4.00	6.00	20.00	*
STRONTIUM — 90 YTTRIUM — 90	$SrCl_2$ YCl_3	25 Yrs. 2.54 Days	0.61 2.18	None None	535	4.00	*	*	*
SULFUR — 35	H_2SO_4	87.1 Days	0.167	None	550		4.00	6.00	10.00
ZINC — 65	$ZnCl_2$	250 Days	0.325 B+	1.12 et al	610		4.00	6.00	*

1. ACA Radioisotope products are packaged in 5ml. aqueous solution. Stable carrier is added unless otherwise specified.
2. License-exempt Radioisotopes are shipped via prepaid first-class mail.
3. All orders must be accompanied by remittance or purchase order.
4. Prices subject to change without notice.

* AEC or State license required for these or larger quantities.

Nuclear Chicago

Noted for slick catalogs and discount ticket books for their radio-nuclides.



ISOTOPE	HALF-LIFE	CHEMICAL FORM	ISOTOPIC CARRIER	NORMALITY OF CARRIER SOLUTION	MAXIMUM BETA ENERGIES (MEV)	PRINCIPAL GAMMA ENERGIES (MEV)
Lead-210 / Bismuth-210	21 years	$Pb(NO_3)_2$	0.1 M	0.1 N HNO_3	Pb, 0.017; Bi, 1.17*	0.047
Cobalt-60	5.27 years	$CoCl_2$	Carrier Free	0.1 N HCl	0.310	1.17, 1.33
Cerium-144 / Praseodymium-144	285 days	$CeCl_3$	Carrier Free	0.1 N HCl	Ce, 0.32; Pr, 2.98	—
Zinc-65	245 days	$ZnCl_2$	$ZnCl_2$	0.1 N HCl	0.325	1.11
Carbon-14	5760 years	Na_2CO_3	1 mg Na_2CO_3	0.1 N NaOH	0.155	—
Carbon-14	5760 years	NH_2CH_2COOH	—	—	0.155	—
Carbon-14	5760 years	CH_3COONa	—	—	0.155	—
Carbon-14	5760 years	$(CH_3CO)_2O$	—	—	0.155	—
Sulfur-35	87.2 days	S in ϕCH_3	0.1 mg/50 μc	Toluene	0.167	—
Sulfur-35	87.2 days	H_2SO_4	0.1 g/l	0.1 N HCl	0.167	—
Iodine-131	8.04 days	Na I	0.5 M	Na OH (pH 10-11)	0.33, 0.61	0.36, 0.64
Phosphorus-32	14.2 days	H_3PO_4	0.25 mg/10 μc	0.1 N HCl	1.71	—
Calcium-45	165 days	$CaCl_2$	1 mg/10 μc	0.1 N HCl	0.25	—

*Also α 5.06

I remained an amateur scientist involved in a large number of non-work related, personal scientific activities for my entire working life.

Rocketry

Electronics

Electrostatics

Tesla coils

Robotics

Nuclear related

Mineralogy

Chemistry

Inertial Electrostatic Confinement

- Discussion of the IECF Concept
- Early Efforts in device construction
- Farnsworth effort to do fusion
- Current academic - professional efforts
- Amateur work in the field

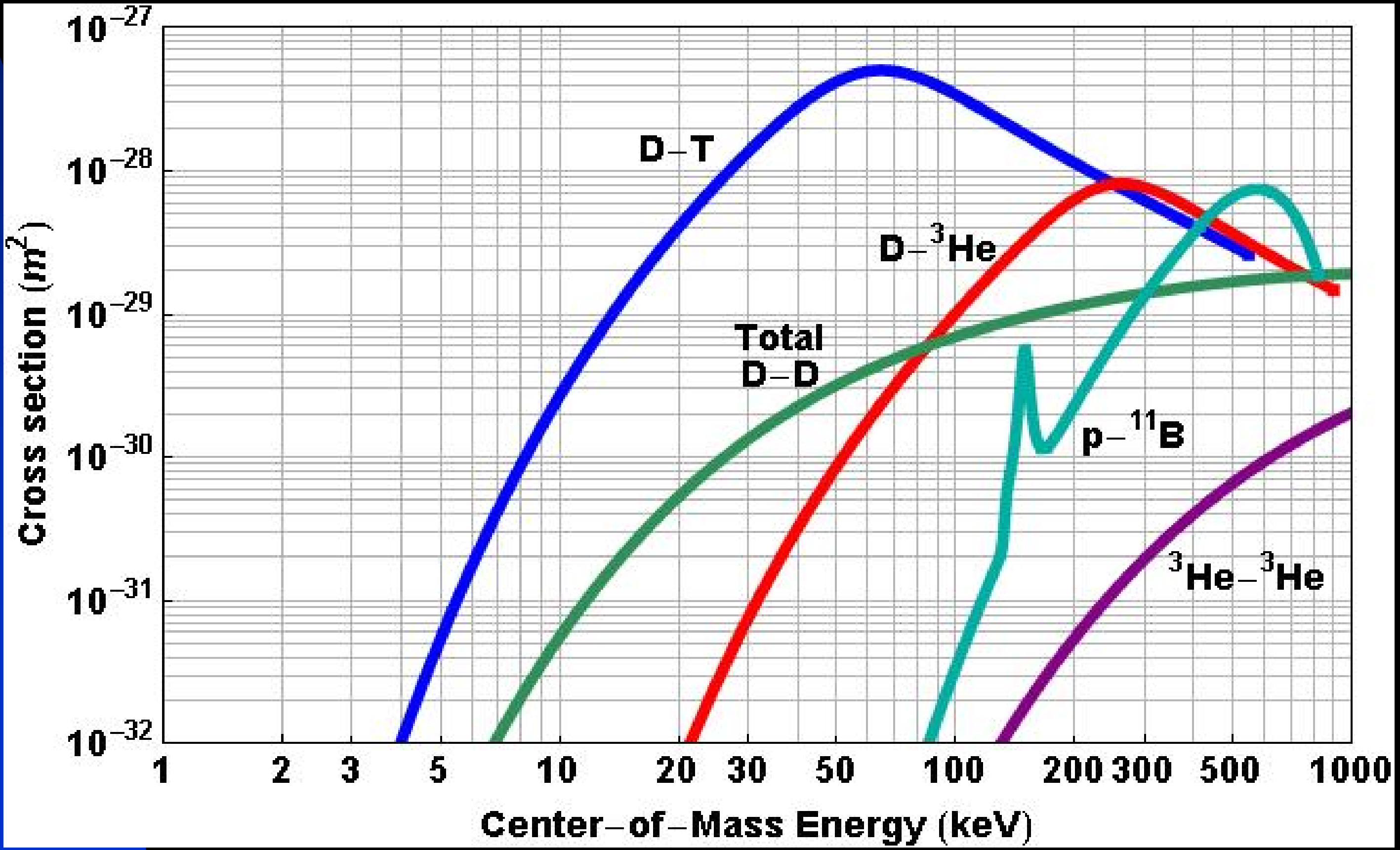
IECF Concept

- To create a non-maxwellian, ionic environment conducive to fusion in velocity space.

The selection of a proper fusion fuel is key to any fusion effort. The Deuterium - Tritium reaction is ideal, but tritium is radiologically nasty and requires a license and NRC oversight.

D – He3 is good at increased voltages but He3 is very expensive.

D-D is ideal as it reacts well at lower voltages and is inexpensive.



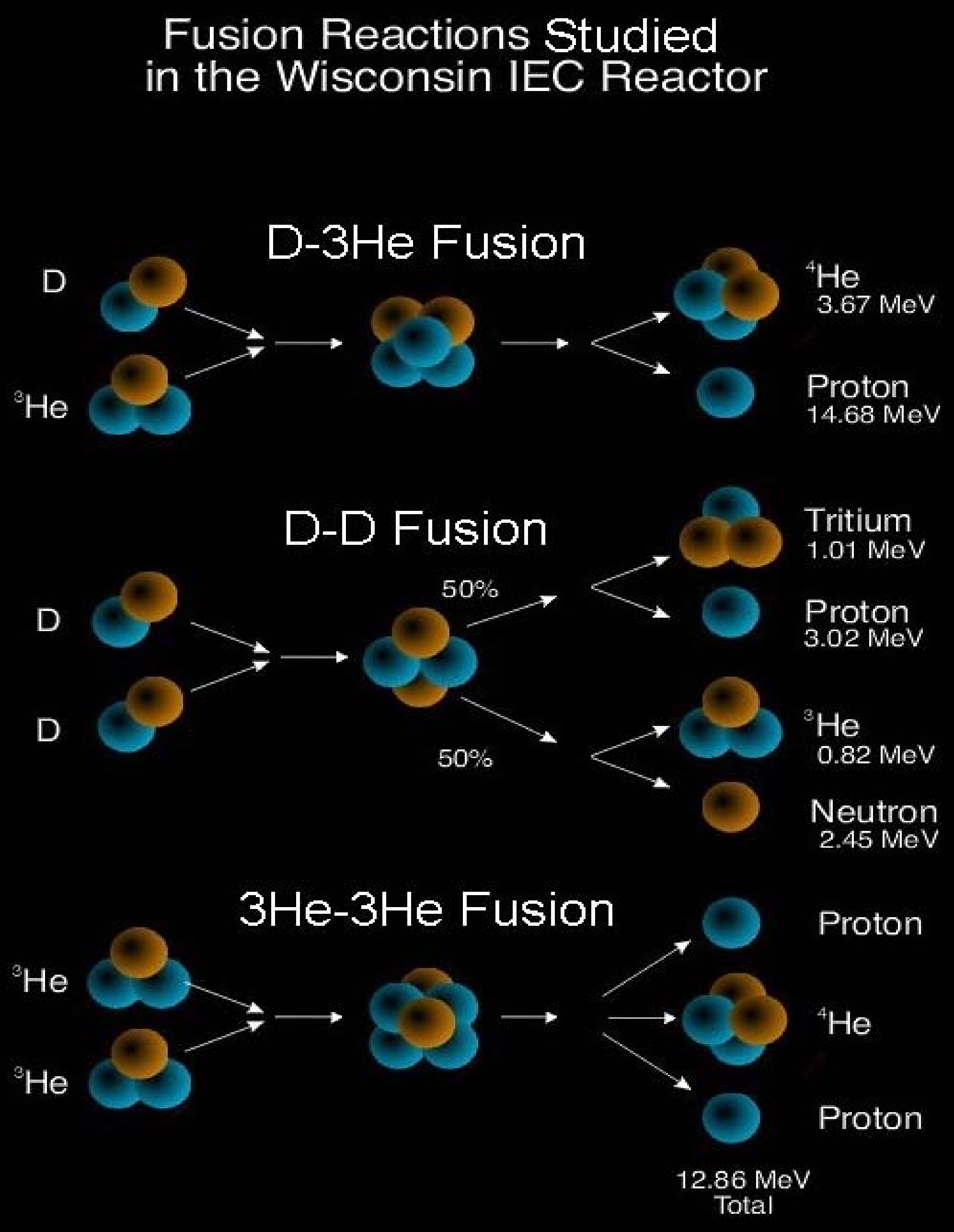
3 reactions that are possible without an NRC license.

Well funded academic programs can work all three.

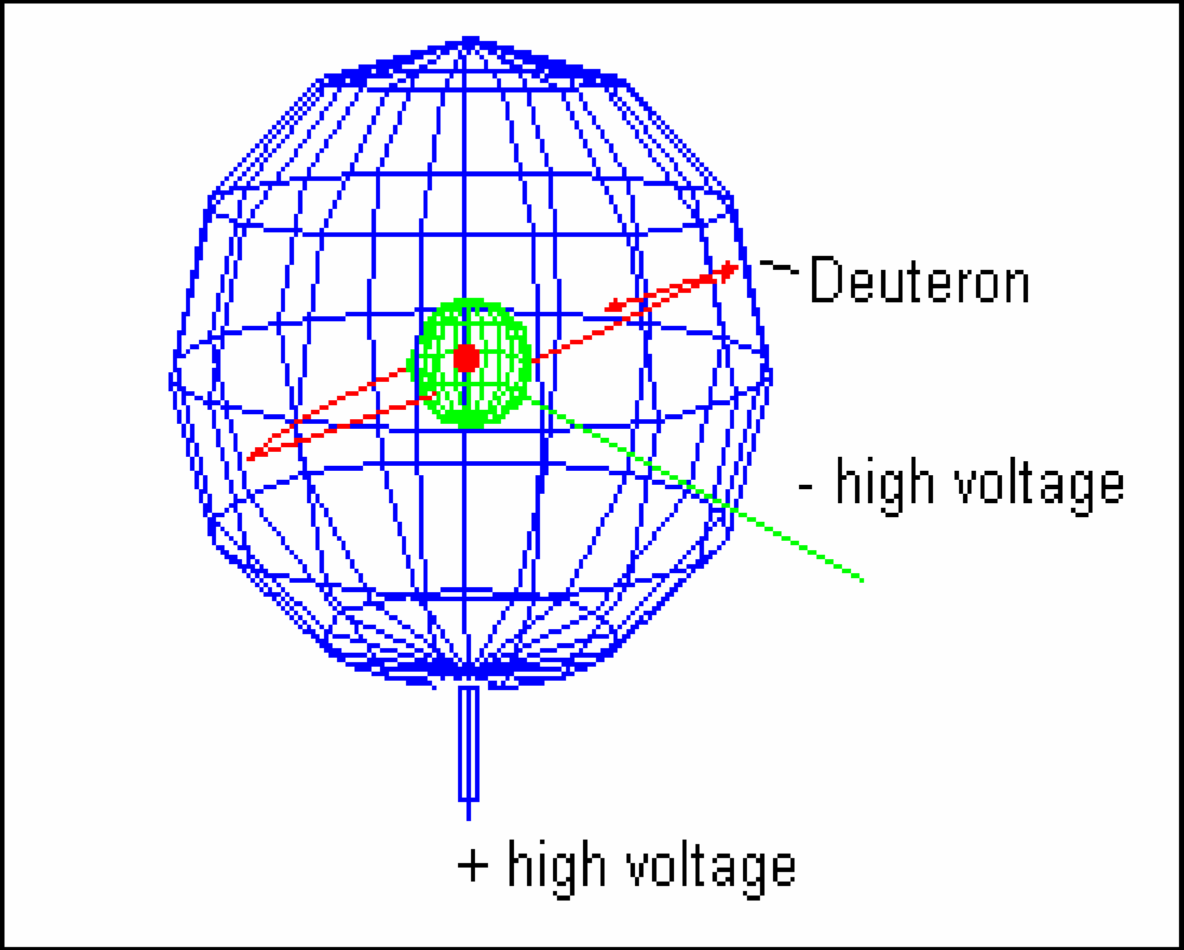
The amateur is limited to the middle or D-D reaction which yields a split 50:50 reaction

D+D to T +Proton

D+D to He3 + neutron



Fuel ions, (deuterons), created near outer grid will accelerate towards inner grid and pass through the electrostatic center of the system and with momentum move to opposite wall area, then turn and re-circulate continuously. Some deuterons will collide head-on at double the applied energy and fuse.



Fly's in the ointment

Collisions with grid

Collisions with ions

Collisions with gas

Neutralization

Early Electrostatic Re-circulating devices

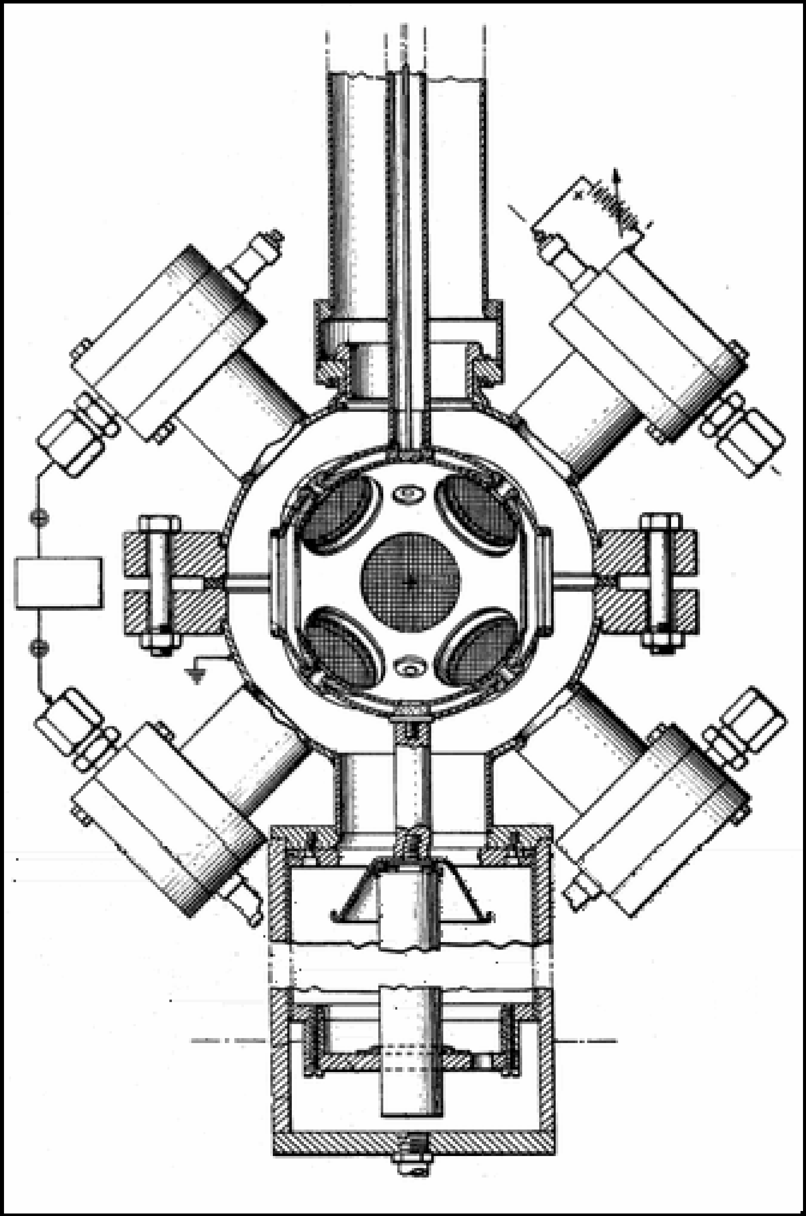
- Spherical diode by Langmuir and Blodgett, 1920's
- Early IEC fusion experiments by Elmore, Tuck and Watson 1940's
- Project Sherwood

Farnsworth Fusor - 1960

- Philo T. Farnsworth – inventor of electronic television devised the full concept of an IECF device
- Work proceeded at ITT on this effort from 1959-1968
- Attempts to interest AEC in continued work on the device in 1968 were unsuccessful.

Farnsworth's device utilized ion guns to inject deuterons into hollow internal cathode to do fusion.

The device improved in performance from 1960 to the final version in 1968 to ultimately produce about 10^{12} Fusions per second using D-T fuel in a 6" diameter reactor.



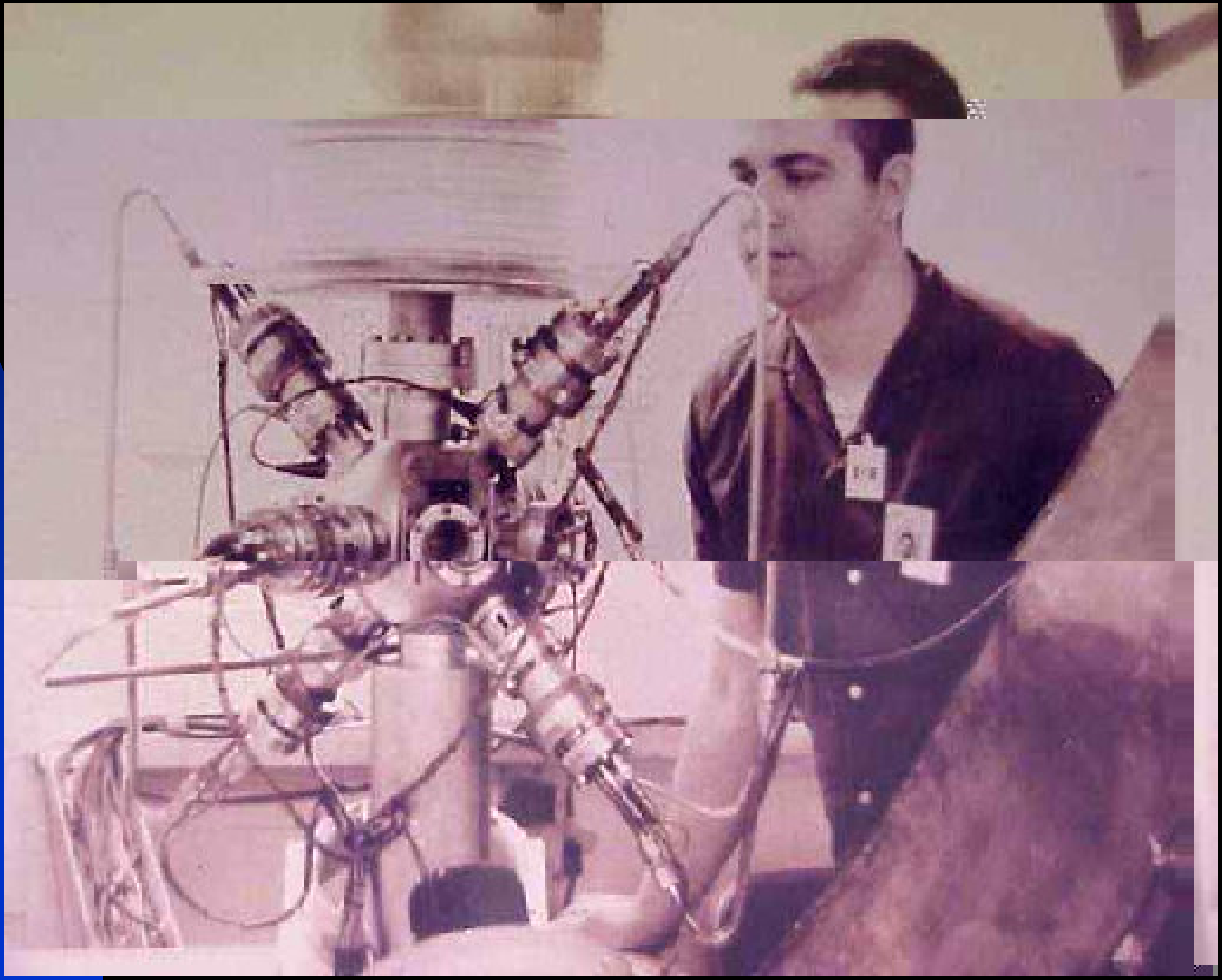
Details about the Farnsworth team's work was retrieved in four separate visits to Fort Wayne, Indiana and many hours of telephone interviews.

In 1999 all team members, save Farnsworth, were still alive.

Gene Meeks with Bob Hirsch’s ion-gunned Fusor in the boron blocked area called the “Cave”…. circa 1966

Hirsch brought many new innovations to the Farnsworth team’s efforts upon joining the team in 1964.

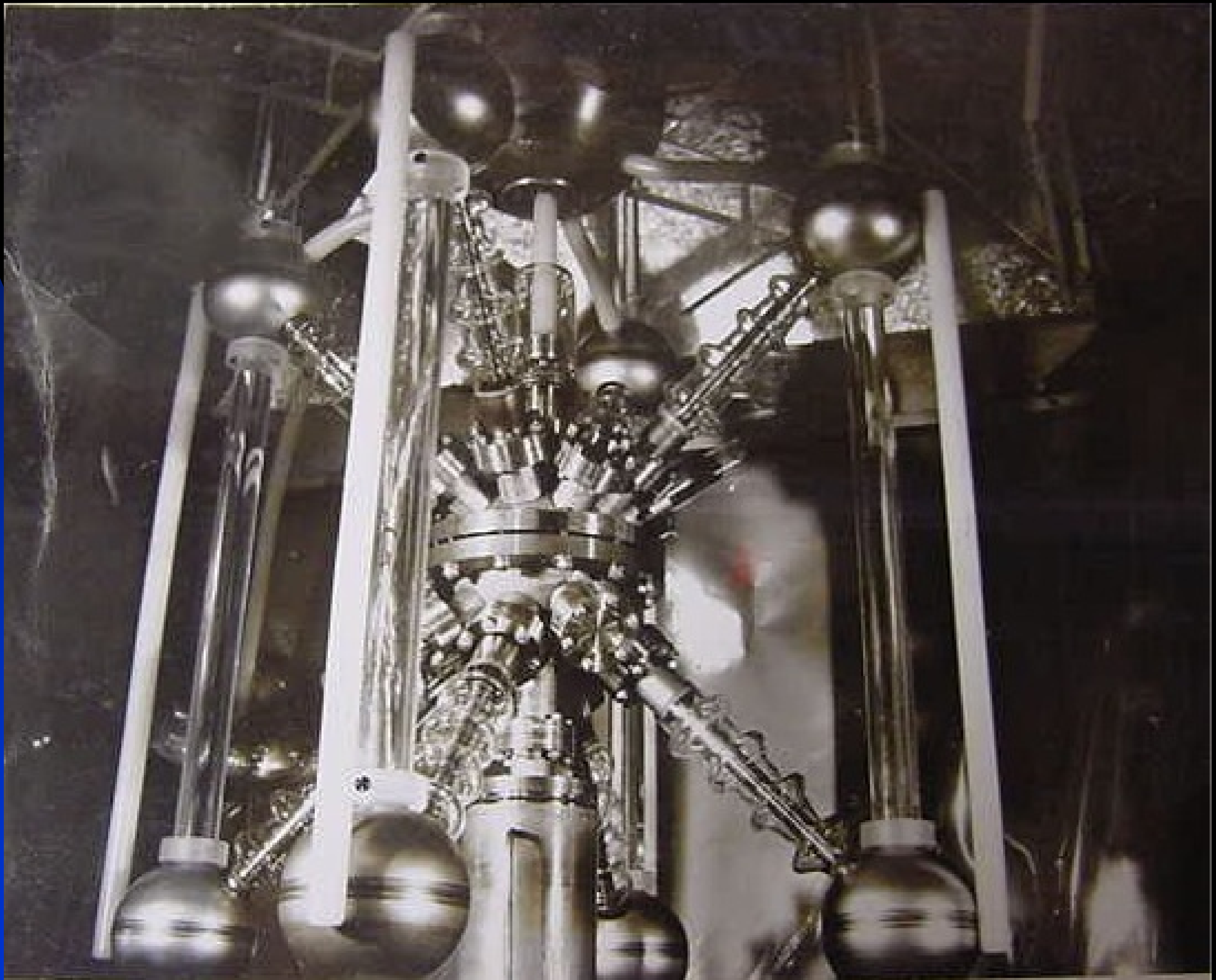
This included the switch over from d-d fusion to d-t fusion fueled devices.



Farnsworth’s Mk II fusor dubbed the “warp core” fusor. Big and time consuming to build and maintain, this d-d fueled device never performed well. Many amateur systems of today can outperform it

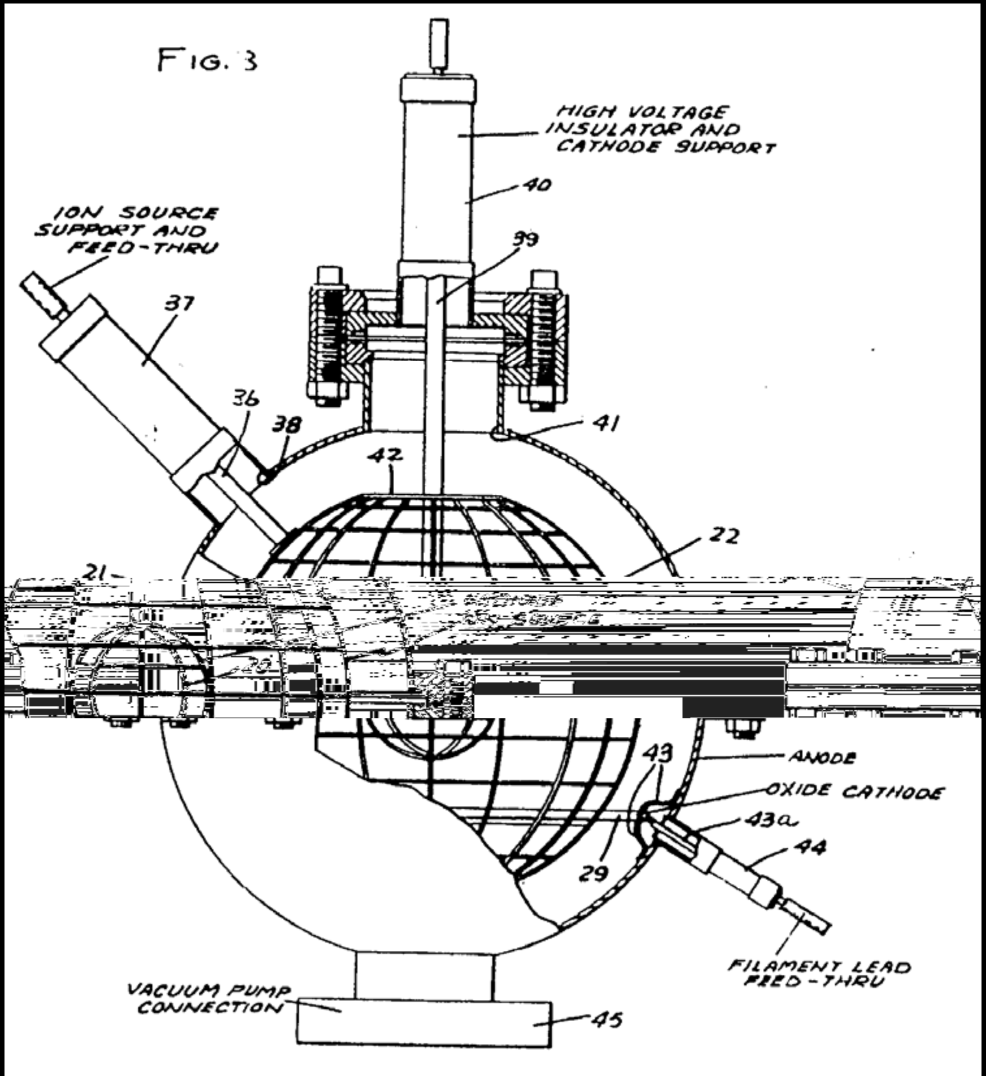
This device was placed on an automobile service station hydraulic lift and descended into a “pit” when operated.

Employees on the top floor above were relocated to avoid “sky shine” irradiation.



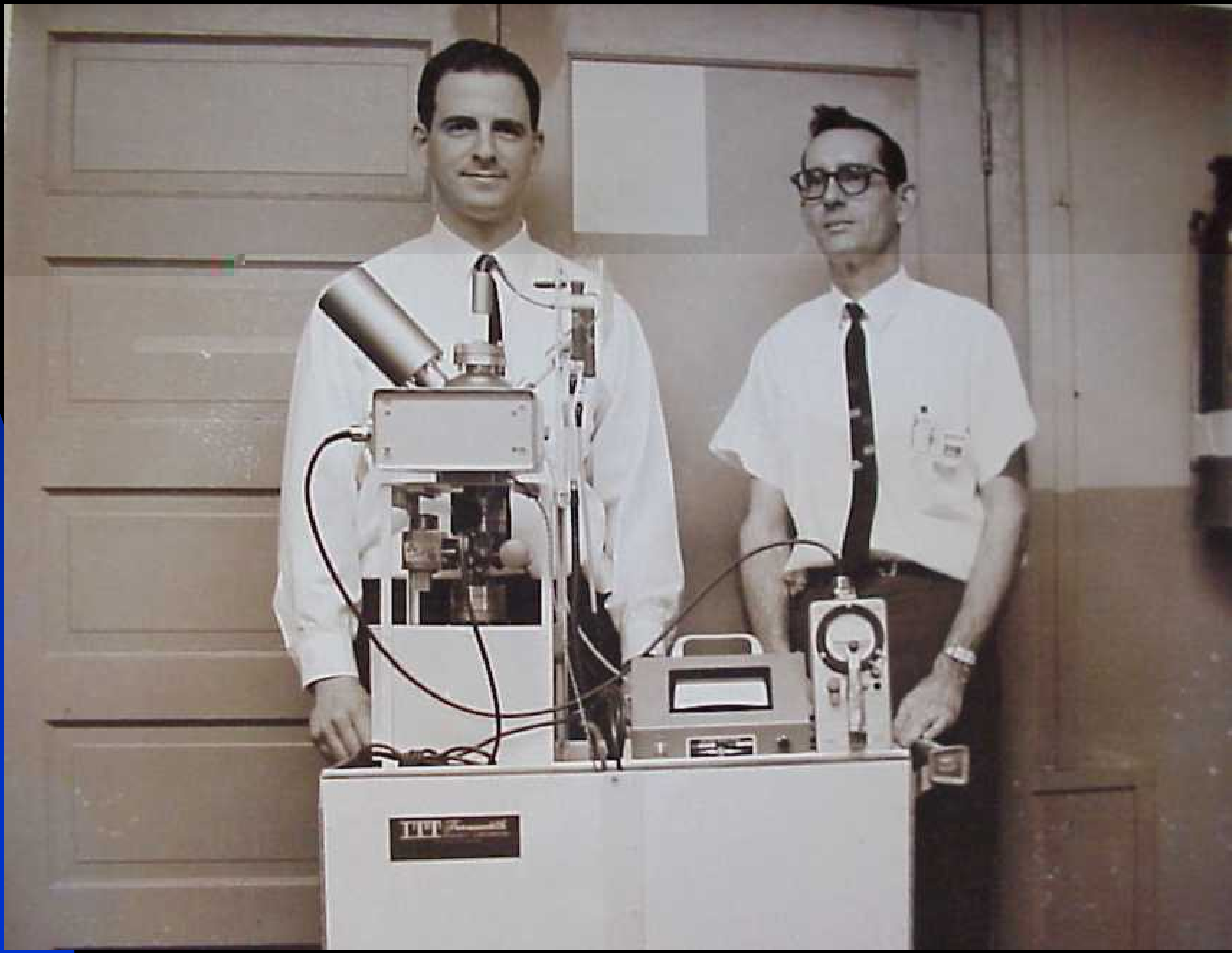
An interesting non-gunned fusor was patented in 1968 as a result of efforts by Bob Hirsch and Gene Meeks. This fusor was the one used in a unique demonstration before the AEC in June 1968

This device and a number of variants based on it would become the main research device used by two major colleges and all amateur fusioneers between 1995 and today.



Robert Hirsch and Steve Blasing pose before the cafeteria plate dispenser cart that was modified to completely contain and transport the Hirsch-Meeks reactor to the AEC in Washington, DC

To have such a device wheeled into a meeting of AEC scientists then plugged into a common wall outlet and produce 10^9 neutrons/sec was un-nerving to those assembled and spending millions on fusion



Dr. Robert Hirsch today in his office with the original AEC demo fusor still in his possession. Hirsch would ultimately head the entire U.S. thermonuclear program in the early 1970's

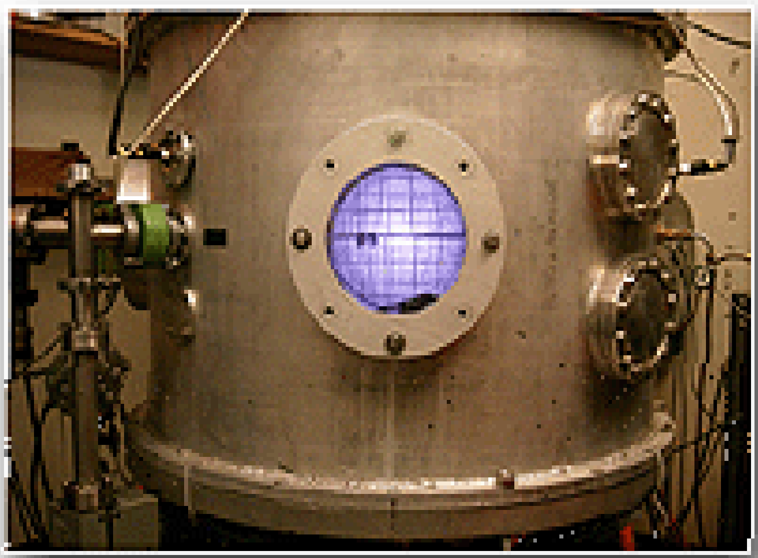
Much to his current regret, Bob would launch the U.S. into the thermal Tokomak programs that have placed millions of the money into "big fusion" research.

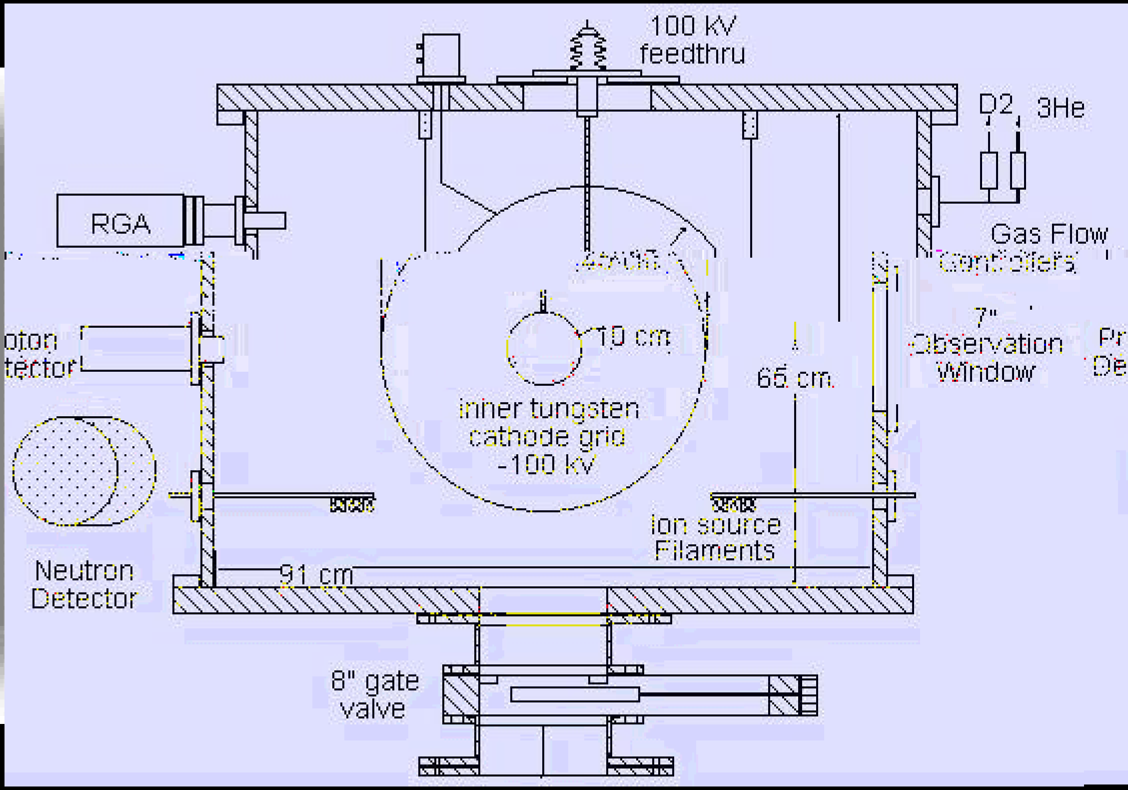
Bob would say in 1999 that if useful fusion can be done at all, it should be able to be done in smaller devices

Fusor programs in academic and amateur settings are instigated by Robert Bussard – Circa 1995

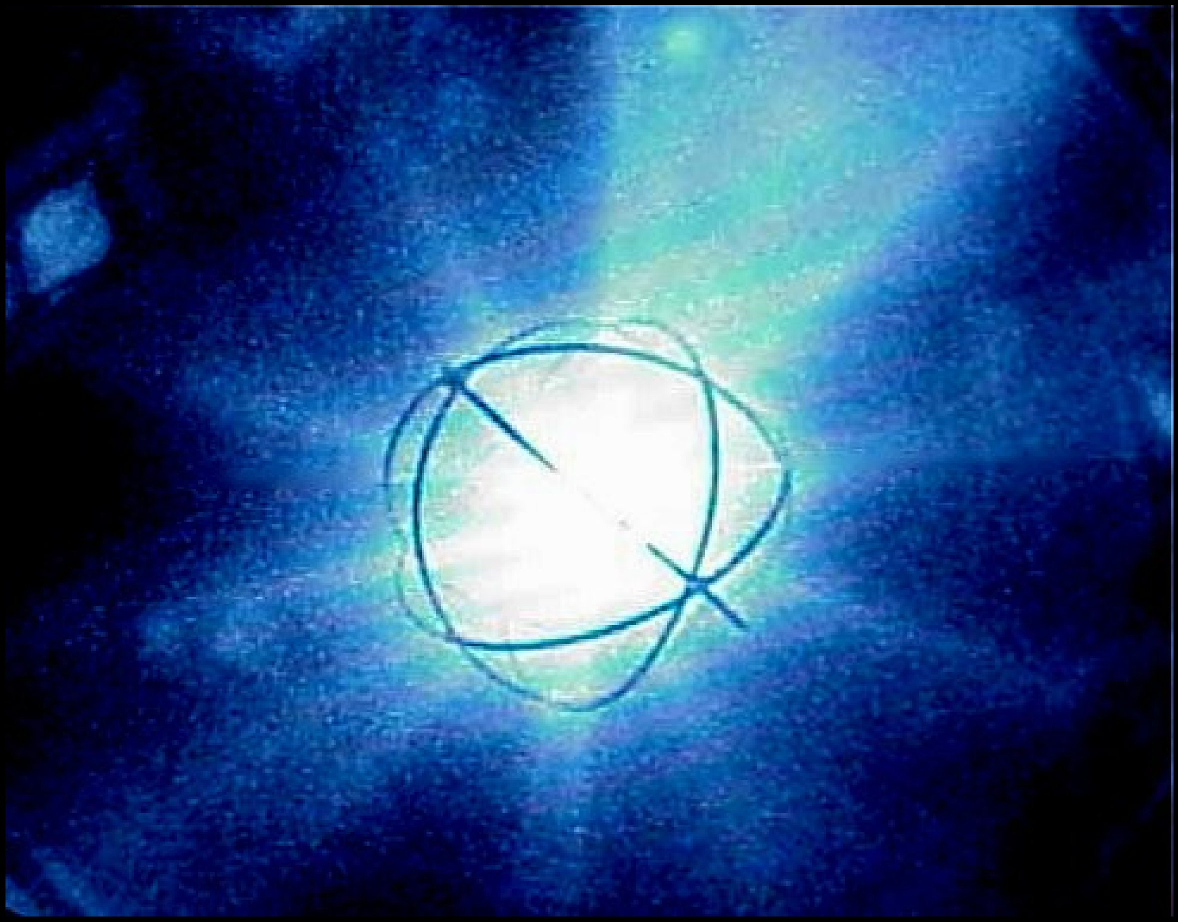
- IECF research started anew in the mid 1990’s at the insistence of Dr. Robert Bussard.
- Academic efforts in fusor based systems begin at the University of Illinois and University of Wisconsin
- Amateur effort is boosted and pushed by Bussard’s chief engineer, Tom Ligon.

The University of Wisconsin fusor system is imaged, on left, and a diagram displayed, on right. This is one of the most well done academic efforts still in full swing in the U.S. It allows students a bit of hands-on in assembly and operation of a fusion device.





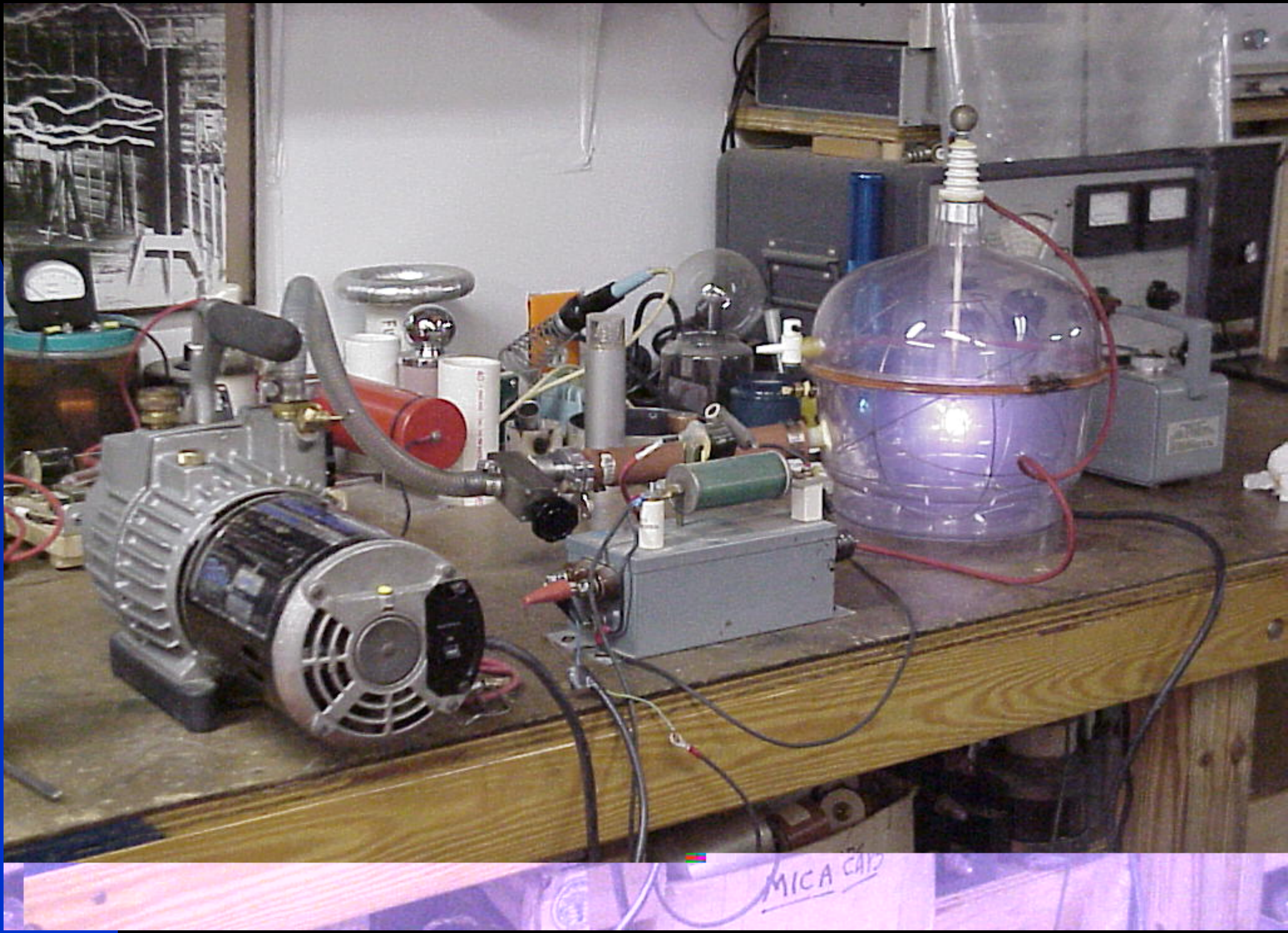
Amateur IECF efforts begin in 1998 and go to the internet in 1999 when Richard Hull becomes the first amateur in the U.S, to do fusion in a modified Hirsch-Meeks fusor.



Fusor I was an ion study system and did not fuse. Termed a “demo fusor”, it is almost always an amateur’s first effort. It allows one to become acquainted with high voltage and vacuum systems - 1997

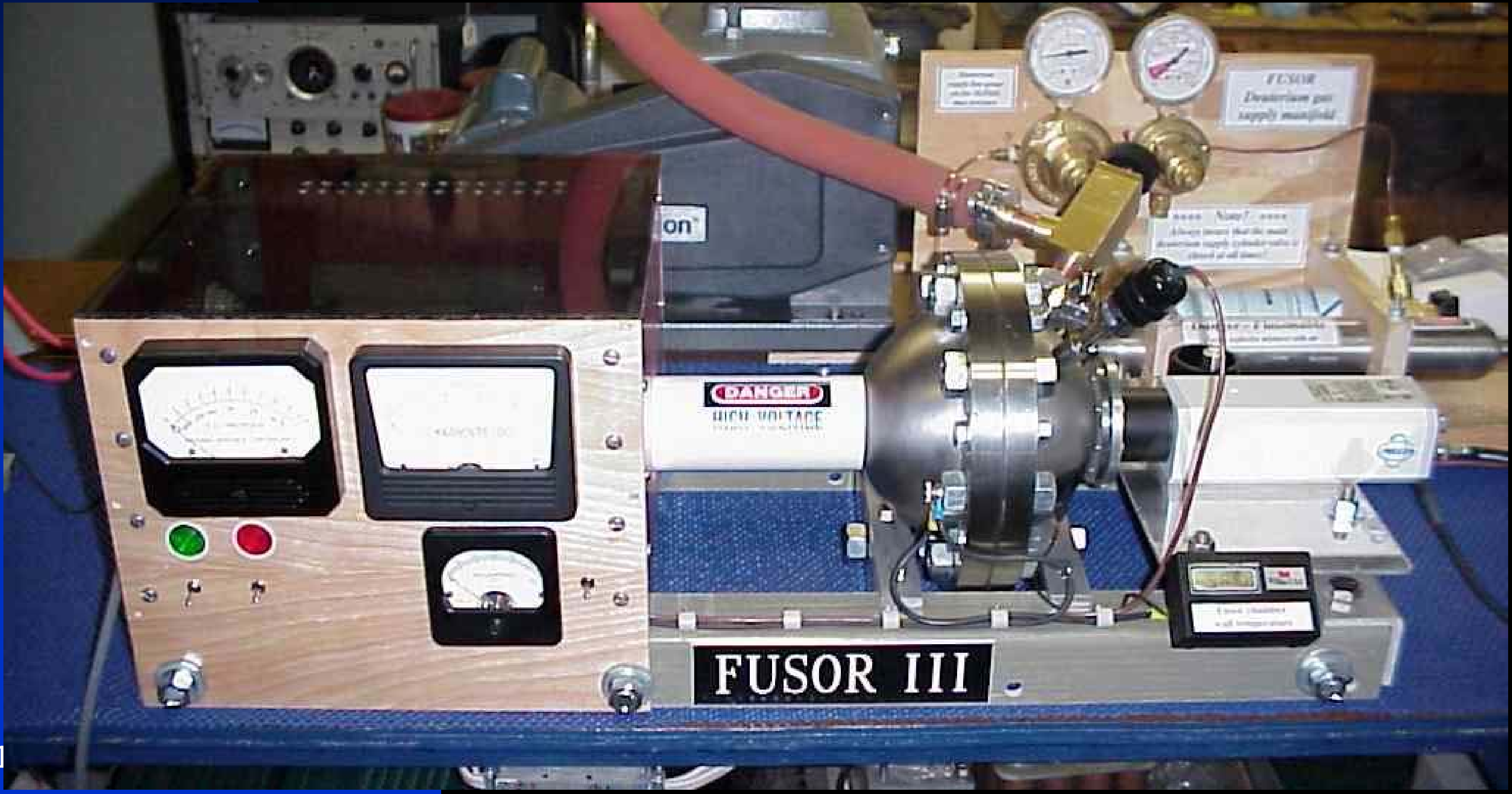
Today, many younger amateurs just build this type of device to win a science fair or as a school science project for credit.

Such systems are relatively inexpensive to construct.



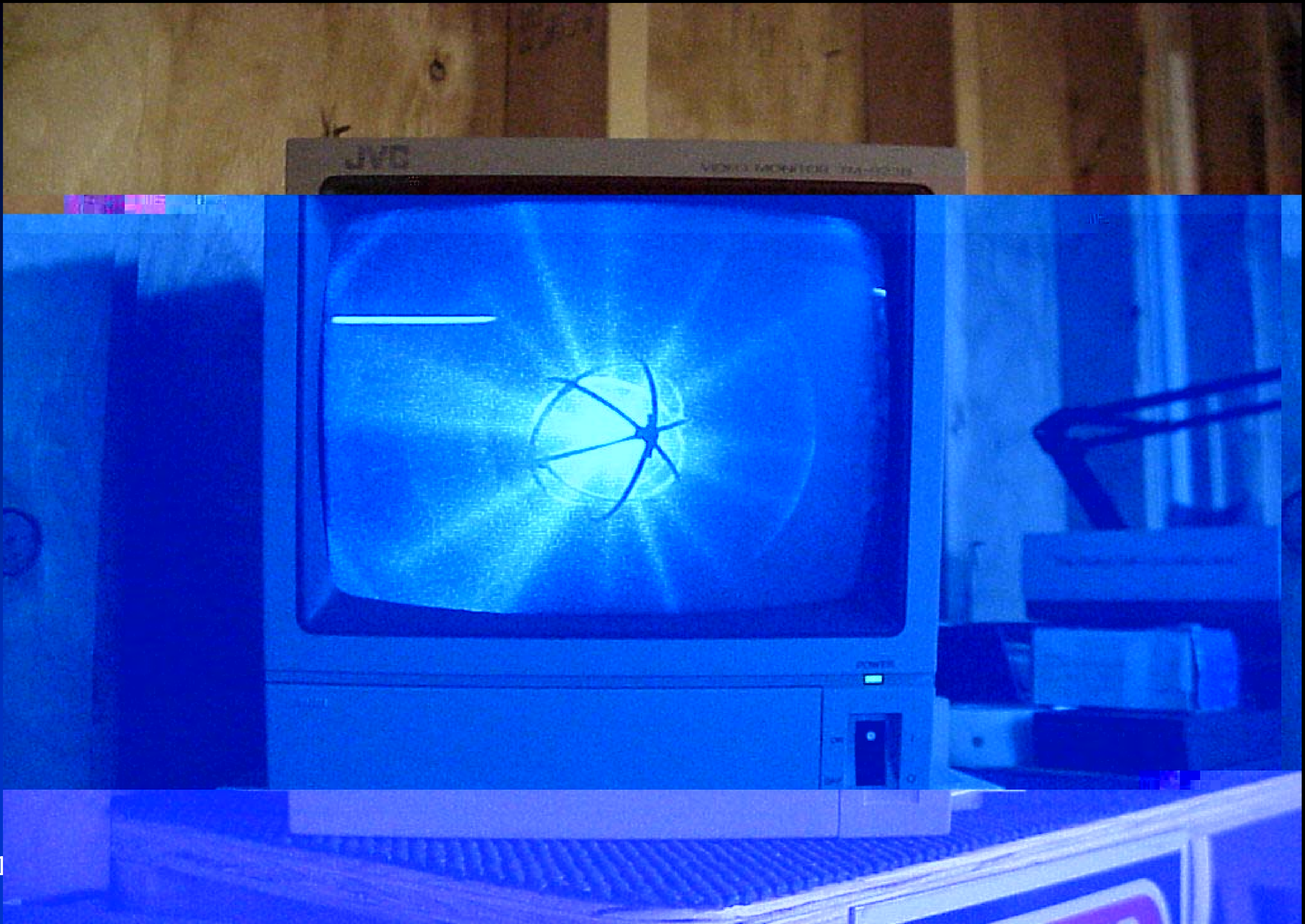
Fusor II was another ion study system, but was a “carry-about” demo system and used a good solid Pyrex bell jar -1998

Fusor III was the first fusor in the U.S. to do nuclear fusion. This early model of the system was transportable. It was limited to low level output by its 22kv internal supply. 10^3 n/sec - Early 1999



Fusor III was placed on a bench and expanded with better neutron detection instruments and a 33 kilovolt supply. 10^5 n/sec
mid 1999

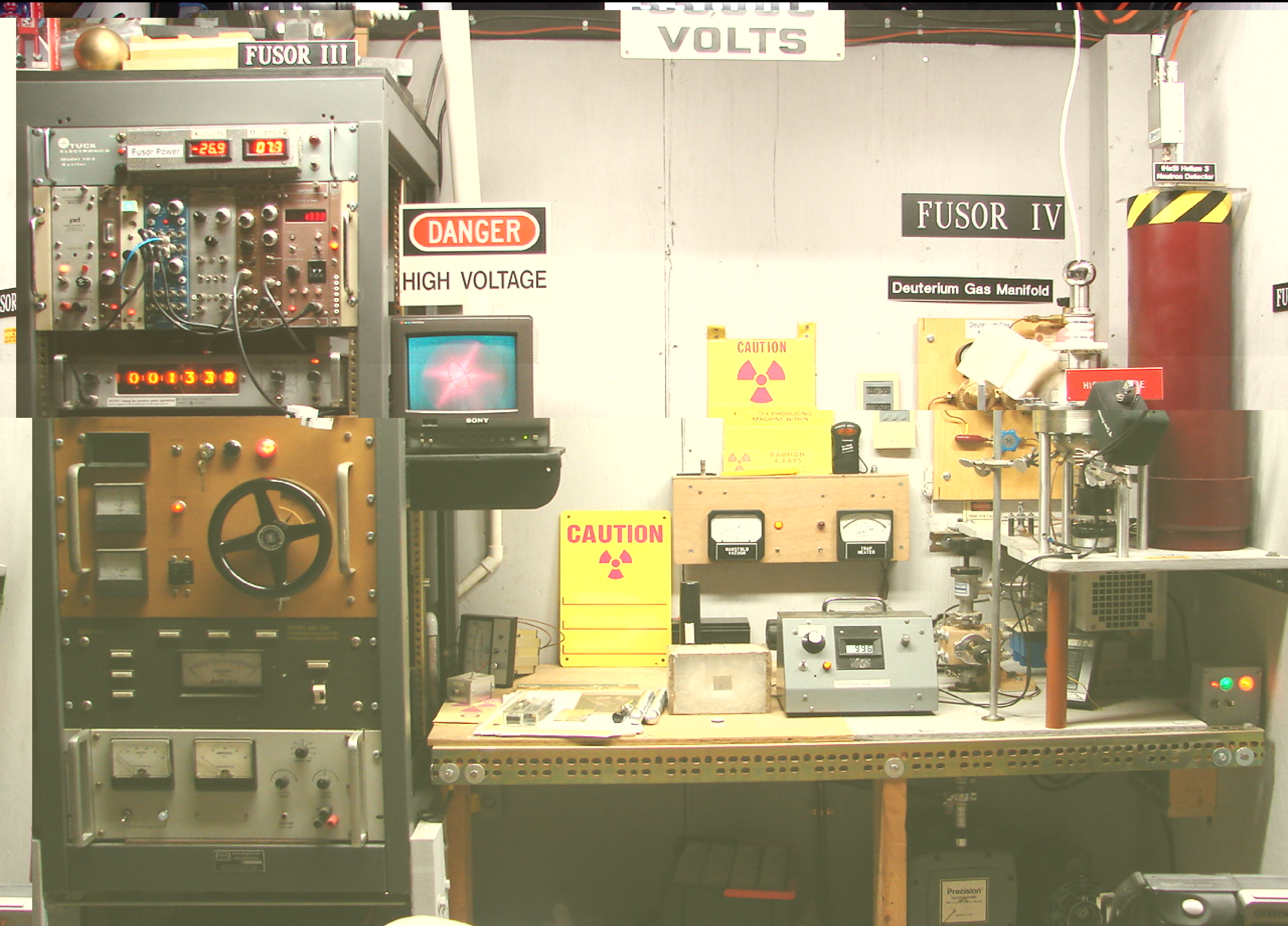
Fusor III sported a video camera to view the reaction zone and star.



In late 2001 work began on Fusor IV This was a system that was to included superb neutron detection instrumentation, a formal conflat flanged and piped stainless steel system that utilized a diffusion pump to achieve very clean vacuums. A redesigned gas handling system was included along with a 45 kilovolt x-ray power supply.

This system has undergone continuous refinement and currently produces in excess of 600,000 neutrons per second which allows some low level neutron activation work of short lived isotopes.

Both light neutron and x-ray shielding are needed beyond this level and the planned fusor V will incorporate these upgrades.



VOLTS
FUSOR III
Fusor Power
DANGER
HIGH VOLTAGE
FUSOR IV
Deuterium Gas Manifold
CAUTION
CAUTION
SONY
Precision

DANGER
33,000
VOLTS
FUSOR III
Fusor Power
Kilovolts
Milliamps
FUSOR IV
CAUTION
Deuterium Gas Manifold
FUSOR IV
SONY

Fast neutron bubble detector acts as backup to electronic detection

I am not the only Amateur Fusioneer

Now for some images of other fusors built by a number of amateurs who learned of the fusor efforts over the internet since 2000

The youngest of these to do fusion was 19 years of age and the oldest 68

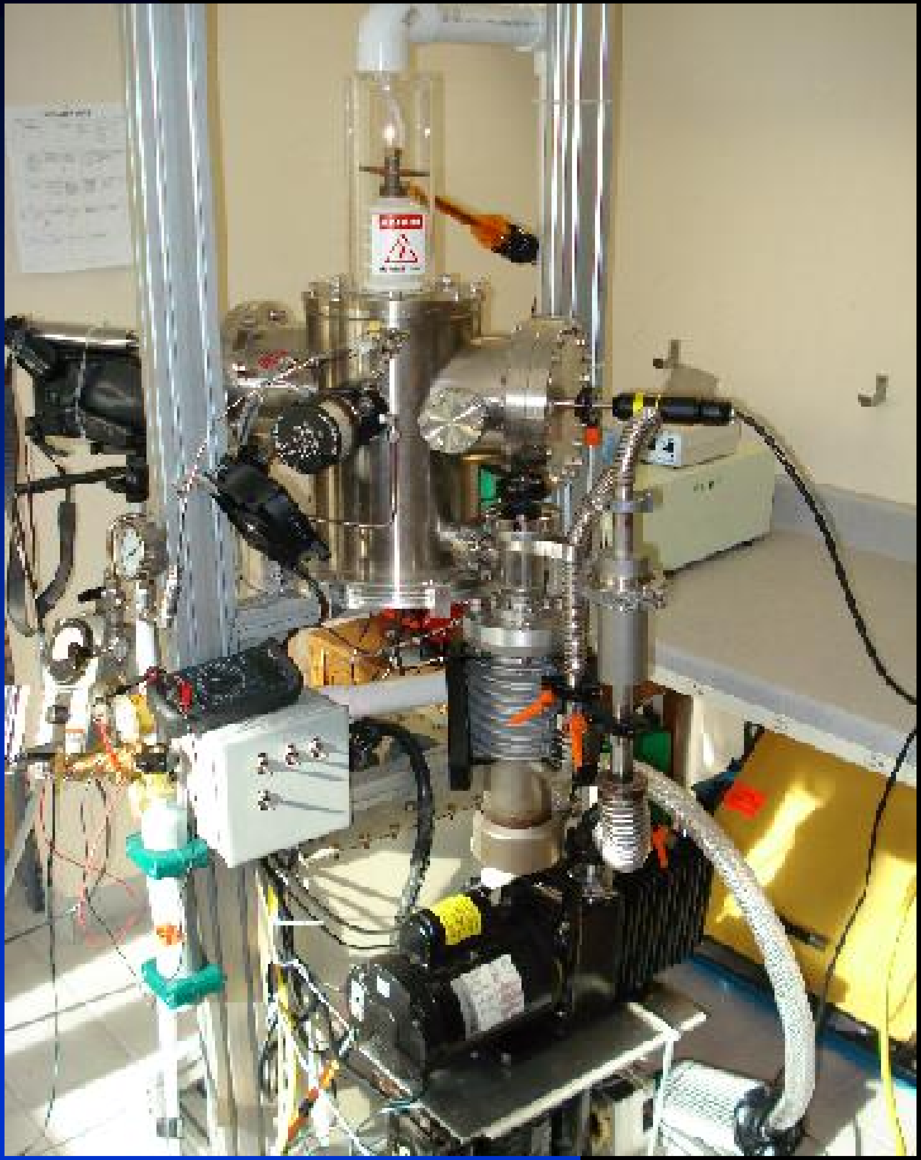
Joe Zambelli – perhaps the most beautiful amateur fusor ever constructed. – Circa 2001

Carl Willis – Now working on his PhD thesis at Los Alamos, he built this while still in high school in 2000 and did some of the earliest activation work with a fusor.

Carl's latest iteration of his fusor is now operating in his cramped apartment in Albuquerque, N.M and is producing over 10^6 neutrons/sec!!

Jon Rosenstiel – Highest output fusor ever made 6 million neuts/sec!

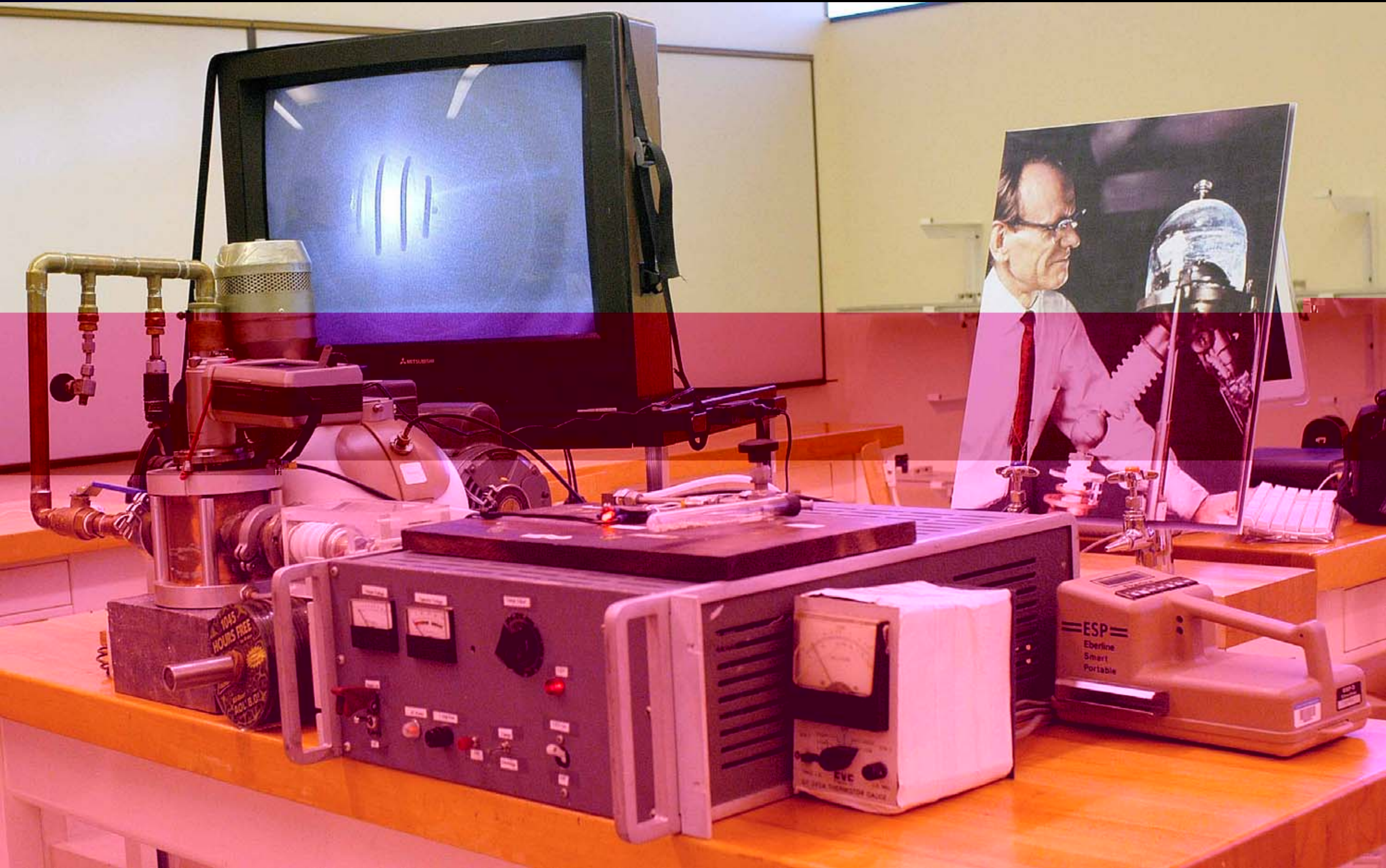
Thiago Olsen – 20 year old college Student. This fusor system was featured in a popular science article recently.



Shortly after the article appeared, his home was visited by his state’s nuclear agency and after testing for x-radiation, his device was approved for home use as it emitted no significant radiation that required a state license or monitoring.

This is the case with all stainless steel fusors operated under 40 kilovolts

Small table top system with spiral wound inner grid



Large, complex, existing vacuum system adapted to do fusion

Tania Herndon - Ireland - Even girls can do it! Tania took first place in her school science fair with a proof of concept “demo fusor” made up from two Pyrex cooking bowls. We see her grinding the lips flat to insure a good gasket seal for the vacuum system. In the image on the right she turns up the high voltage to get a “star”

Efficiency - Will the fusor or the IECF concept deliver power ?

The simple answer is, no, it will not.

The best amateur fusors that produce over $10e^6$ fusions per second consume about 600 watt-seconds of energy and produce less than a microwatt-second of total fusion energy!

This is a net energy loss of almost a billion to one.

Still, to have done nuclear fusion on a table top, created a usable small neutron source with one's own hands, and within a limited budget, is quite an accomplishment. One must become acquainted with many different scientific, engineering, mechanical and material selection disciplines in order to safely succeed in the construction of this amateur fusion device.

It is all for the sake of the learning and the doing that one undertakes such a daunting task, especially at younger ages.

END